Trabeculectomy – the Moorfields Safe Surgery System

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Introduction

This chapter addresses the current techniques used in glaucoma filtration surgery, in particular a guarded sclerostomy procedure best known as trabeculectomy. The decision to perform glaucoma surgery represents a key point in the long-term management of the patient's disease, and should only be made after detailed consultation with the patient. The timing of surgery and selection of appropriate procedure need careful consideration and consultation. It is important to remember that the pre-operative and post-operative management are critical determinants of the outcome of glaucoma surgery.

The field of glaucoma surgery is undergoing a period of revolution with many new approaches to the traditional methods of surgery. Like all surgery, it is essential that surgeons have a sound understanding of the principles involved in the modern range of surgical procedures, and keep up to date with new procedures so that technique can be varied depending on the surgical circumstances. An example of a new techniques that have revolutionised glaucoma surgery and are still changing is the use of adjuvant therapies to modify post-operative wound healing. The identification of relative risk factors for failure of glaucoma surgery enables the surgeon to vary the adjuvant therapy as appropriate while minimising the risk.

Glaucoma filtration surgery was previously performed when patients had uncontrolled intraocular pressures on maximally tolerated medical treatment, or after failed laser trabeculoplasty. The main reasons for delaying surgery were the risk of post-operative complications associated with standard trabeculectomy procedures and high failure rates for operations in certain sub-groups of glaucoma patients. Technical modifications to the trabeculectomy procedure including adjustable stitch techniques combined with the use and techniques of application of these powerful antimetabolites now enable the surgeon to have much greater control of both the operation and post-operative scarring. The identification of patients at risk of developing post-operative hypotony and the continuing development of surgical measures to reduce this risk have been important advances. The risks of surgery in each individual patient should be balanced against the projected visual loss which will occur from glaucomatous damage if the intraocular pressures are not adequately controlled. The
techniques described in the following sections are continuously changing with the aim of making glaucoma surgery as safe and successful as possible.

**Anaesthesia**

The various operations described in this chapter can be carried out under local or general anaesthetic. The methods of anaesthesia are covered in another chapter in this book. However, there are specific points in terms of anaesthesia in glaucoma.

1) **General anaesthetic**

The lowering of intraocular pressure with anaesthesia can be used to advantage by the ophthalmic surgeon if intraoperative pressure lowering is required. Blood pressure and to some extent choroidal volume can be reduced if necessary by varying the anaesthetic in patients at risk of choroidal haemorrhage.

2) **Local anaesthetic**

When performing glaucoma surgery under local anaesthesia it is important to try and avoid unnecessary elevation of IOP. It is advisable to use a technique that paralyses orbicularis oculi to prevent eyelid squeezing and increased pressure on the globe. Patients with pre-existing glaucoma may have a marked elevation in their IOP during peribulbar or retrobulbar anaesthesia. This may be particularly important in patients who have advanced visual field loss. Reduced volumes of local anaesthetic agents with hyaluronidase should be used in these patients if necessary, and orbital compressive devices (e.g. mercury balloons) should be avoided if possible. Buphthalmic or myopic eyes often have extremely long axial lengths and may have large posterior staphylomas with the attendant risks of inadvertent ocular perforation during retrobulbar or peribulbar anaesthesia. Patients occasionally notice an enlargement of their scotoma as a retrobulbar anaesthetic takes effect, this is reversible but patients need to be warned of this. In an only eye, this may render the patient effectively blind for many hours. General anaesthesia may be preferable in these patients as it avoids this problem and allows increased control of the operative conditions. Filtration surgery can also be carried out using only sub-conjunctival anaesthesia. However, the patient may experience pain when the iris is handled particularly when an iridotomy is performed. Intracameral anaesthetic may potentially be useful in this context.

**Filtration surgery - pre-operative details**

The risks of any form of surgery should be explained to the patient in advance. In particular it is vital to explain that surgery for glaucoma is usually done to preserve vision not to improve it. Patients should be warned that their vision may well be blurred in the weeks after surgery before approaching pre-operative levels. Several studies have demonstrated a loss of best-corrected visual acuity (of about 1 line) in post-operative patients, and it is essential that patients are aware of this. Patients with advanced field loss should be told of the risks of loss of their remaining field, the so called "wipe out" event, although this is extremely rare. Patients who wear contact lenses should be advised that this may not be possible after filtration surgery.

**Pre- and intraoperative drops**

1) **Parasympathetic agonists.** Pilocarpine eye drops are sometimes used pre-operatively to miosis the pupils. In theory, this protects the cornea from lens-corneal touch, and may reduce the chance of inadvertently cutting an excessively large iridectomy. The disadvantages include
shallowing of the anterior chamber, and a theoretical possibility that the blood/aqueous barrier may be further compromised. Long acting anticholinesterase agents should be discontinued if possible to reduce blood vessel congestion and leakage.

2) **Sympathetic agonists.** Topical adrenaline can be used at the beginning of the operation. Solutions of 0.01% or 0.1% can be dropped on the field of surgery. This produces conjunctival vasoconstriction and a reduction in bleeding during the course of the procedure. Blood contains many growth factors that promote wound healing and increase the chance of filtration surgery failure. The disadvantage of using adrenaline, is that it does cause some pupillary dilatation. However, this is not usually a problem, particularly if the operation is carried out relatively rapidly.

3) **Povidone -Iodine.** Povidone iodine has a broad spectrum of anti-microbial action. It can be used to prepare the skin, and drops can be applied to the superior and inferior fornix, to kill any bacteria. This is particularly important if the patient has pre-existing conjunctival or lid disease, which predisposes them to bacterial colonisation.

4) **Steroids** It has been shown that chronic pre-operative topical treatment jeopardises filtration surgery by increasing the number of fibroblasts and inflammatory cells in the conjunctiva. This is particularly marked in association with the long-term use of adrenergic agents such as adrenaline and dipivefrin. Topical steroids such as fluoromethalone reverse the histological change in the conjunctiva, although whether this conclusively increases the success rate has not been proven.

5) **Non steroidal anti-inflammatory drugs**. The use of pre-operative non-steroidal anti-inflammatory drugs such as indomethacin or flurbiprofen has not been proven to alter the long-term results of glaucoma filtration surgery. However, in patients who may require iris manipulation and who in addition have a risk of fibrinous uveitis (especially dark irides) our impression is that pre-operative topical steroids and non-steroidal drops may be useful, even for a period as short as 24 hours before surgery.

6) **Hypotensive agents.** If possible aqueous suppressants particularly those that have long acting effects such as beta-blockers should be stopped several days in advance with outpatient monitoring. This will optimise aqueous flow post operatively, encouraging aqueous flow through the new channel and help to prevent hypotony.

**Surgical technique for trabeculectomy**

1) **Position of filtration area.** Filtration surgery is most commonly performed in the superior half of the globe. This is because the upper lid protects the drainage area. A peripheral iridectomy placed at 12 o'clock is covered by the lid, and does not give rise to diplopia. Drainage blebs that are not covered by the upper lid, particularly those in the interpalpebral fissure or the lower fornix, have a high incidence of inflammation and endophthalmitis especially when antimetabolites have been used. Scleritis may also be more common, particularly with the use of antimetabolites. It is important to avoid positioning the bleb anywhere other than the superior limbus, and other procedures should be used if this is not possible.

2) **Traction suture.** Superior rectus traction sutures are still commonly used. However, the use of a corneal traction suture is becoming increasingly popular. This is because there is no chance of creating a superior rectus haematoma. Such a haematoma results in the release of growth factors that trigger wound healing. The vector force of the corneal suture is superior to that achieved with a superior rectus suture. The disadvantages of the corneal traction suture include the small risk of placing the suture too deeply and penetrating the anterior chamber (great care in buphthalmic eyes),
and the chance of placing the suture too superficially with subsequent "cheese-wiring" and loss of traction. A variety of sutures can be used, but we use a 7-0 black silk suture on a semi-circular needle.

(Figure 1 Corneal traction suture)

3) *Conjunctival incision.* The conjunctiva can be incised at the limbus (fornix-based flap) or deep in the fornix (limbus-based flap). The advantages and disadvantages of either approach are summarised in table 1

<table>
<thead>
<tr>
<th></th>
<th>Fornix</th>
<th>Limbus</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Length of operation</strong></td>
<td>Faster than limbus based</td>
<td>Slower than fornix based</td>
</tr>
<tr>
<td><strong>Sclerostomy exposure</strong></td>
<td>Good</td>
<td>Reasonable</td>
</tr>
<tr>
<td><strong>Large eye/small eyelid fissure</strong></td>
<td>Technically easier</td>
<td>Difficult</td>
</tr>
<tr>
<td><strong>Area dissected/damaged</strong></td>
<td>Smaller</td>
<td>Larger</td>
</tr>
<tr>
<td><strong>Releasable suture placement through cornea</strong></td>
<td>Simple</td>
<td>More difficult</td>
</tr>
<tr>
<td><strong>Conjunctival wound leaks</strong></td>
<td>Increased incidence Rare if buried corneal mattress sutures used</td>
<td>Less common if deep in fornix</td>
</tr>
<tr>
<td><strong>Antimetabolite application</strong></td>
<td>Need multiple small sponges Great care needed to insert</td>
<td>Fewer sponges needed Easy to insert sponge without touching wound edge</td>
</tr>
<tr>
<td><strong>Post operative appearance</strong></td>
<td>More diffuse (esp with MMC)</td>
<td>More focal (esp with MMC)</td>
</tr>
<tr>
<td><strong>Reoperation</strong></td>
<td>Technically easier</td>
<td>More difficult</td>
</tr>
</tbody>
</table>
The conjunctiva should be handled very gently to avoid buttonholing, particularly if antimetabolites are used. If a limbus based flap is used, the incision should be made far into the fornix. The conjunctiva and Tenon's should be entered in separate layers to minimise the chance of damaging the superior rectus muscle. An incision length of at least 10 mm is usually necessary to provide adequate exposure. For a fornix based flap an incision of about 5-10 mm is necessary. A relieving incision is used by many surgeons but is not necessary and increases the trauma and risk of wound leakage.

We always previously used a limbus-based incision with antimetabolite as we were worried about postoperative leaks. However, my clinical observation of cystic blebs led me to the hypothesis that they had two things in common. The first was restricted posterior flow “the ring of steel”. The second was anterior aqueous flow. Even cystic blebs from pre-antimetabolite days have these features.

The restricted flow from the posterior incision resulting in more focal cystic blebs led us to change. The effects of treatment were very focal and the cells at the edge of the treatment area although growth arrested and can make scar tissue and encapsulate the area resulting in thinning and a cystic bleb. A fornix-based incision allowed a larger area of antimetabolite treatment, without a posteriorly placed restricting scar.

Similar blebs can be achieved with a limbus-based flap but the incision has to be very posteriorly placed and this result is not as consistent. This does make the subsequent scleral flap and sutures more difficult.

5) Scleral flap There are several types of scleral flap. The two most common types being rectangular and triangular in shape. There is no evidence that one is superior to the other. The scleral flap is usually outlined, and a lamellar dissection is carried out with a blade or scleral pocket knife. Alternatively, with a rectangular flap an incision can be made, and a scleral pocket made (like a phaco emulsification pocket) and then the two side incisions cut at the end.
The side incisions are not cut right to the limbus as this encourages posterior flow reducing the incidence of cystic blebs. We now cut the scleral flap before applying antimetabolite. There is also evidence that treatment under the flap increases the success rate and experimental and clinical evidence to suggest this is safe. We try to cut the largest flap possible and leave the side cuts at the limbus incomplete (1-2 mm from limbus). This forces the aqueous backwards over a wider area to get a diffuse bleb. An aqueous jet at the limbus predisposes to an anterior focal cystic bleb, whereas posteriorly directed diffuse flow of aqueous from incompletely cut sides of a large scleral flap results in a more diffuse non-cystic bleb.

The main function of the scleral flap is to provide resistance to aqueous outflow and prevent hypotony. To perform these functions the flap must be sufficiently large to cover the sclerostomy. It is important that the scleral flap is not too thin, since this increases the chance of flap dehiscence. Additional problems include formation of holes in the flap and cheese-wiring of the flap sutures. All these complications allow increased aqueous leakage and reduce flap resistance.

This is particularly important with the use of anti-metabolites, because the conjunctival resistance to outflow may not rise for several weeks or even months after surgery. This is also very important in eyes with thin, less rigid sclera such as buphthalmos and myopia. If the scleral flap does not provide adequate resistance, the eye will be hypotonous. It is important to remember that the limbus may be thinned after multiple surgery or cryotherapy. If there is a large aqueous vein running through the site of the potential scleral flap, this vein should be avoided, as when the flap is cut, the vein will end up as a perforating hole in the scleral flap. Scleral flap sutures are pre-placed at this stage whilst the eye is still firm. Scleral flap sutures are more difficult to place once the eye has been entered and is hypotonous.

4) Intraoperative antimetabolite use   The full details of all antiscarring agents are too extensive for this chapter and are covered elsewhere. However the many potential agents are summarised in table 2.

Table 2: Sequence of events in tissue repair and possible types of modulation after glaucoma filtering surgery (events and agents have overlapping time duration and action) Modified from Khaw et al Curr Opin Ophthalmol 2001:12:143-148

<table>
<thead>
<tr>
<th>Event</th>
<th>Possible modulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activated conjunctiva</td>
<td>Stop medical therapy (esp drops causing red eye)</td>
</tr>
<tr>
<td>“pre-activated” cells</td>
<td>Pre-operative steroids</td>
</tr>
<tr>
<td>Conjunctival/episcleral/scleral incisions</td>
<td>Minimal trauma</td>
</tr>
<tr>
<td>Damage to connective tissue</td>
<td>Less invasive surgical techniques</td>
</tr>
<tr>
<td>Release of plasma proteins and blood cells</td>
<td>Haemostasis (Blood can reverse MMC)</td>
</tr>
<tr>
<td>Activation of clotting and complement</td>
<td>Agents preventing/removing fibrin e.g. heparin, tissue plasminogen activator, hirudin</td>
</tr>
<tr>
<td>Fibrin/fibronectin/blood cell clot</td>
<td></td>
</tr>
<tr>
<td>Release of growth factors from blood</td>
<td>Antagonists to growth factor production</td>
</tr>
<tr>
<td></td>
<td>e.g. antibodies to growth factors humanised anti TGF-beta2 antibody (CAT 152 Trabio®) or receptors</td>
</tr>
<tr>
<td></td>
<td>Anti-sense oligonucleotides, ribozymes</td>
</tr>
<tr>
<td></td>
<td>Less specific antagonists e.g. tranilast, genistein, suramin</td>
</tr>
<tr>
<td>Aqueous released from eye</td>
<td>Blood aqueous barrier stabilising agents</td>
</tr>
<tr>
<td>Breakdown of blood aqueous barrier</td>
<td>e.g. Steroids</td>
</tr>
<tr>
<td>Release of growth factors into aqueous</td>
<td>Non-steroidal anti-inflammatory agents</td>
</tr>
<tr>
<td>Aqueous begins to flow through wound</td>
<td></td>
</tr>
<tr>
<td>Migration and proliferation of Polymorphonuclear neutrophil cells, macrophages and lymphocytes.</td>
<td>Anti-inflammatory agents e.g. steroids/cyclosporine</td>
</tr>
<tr>
<td></td>
<td>Anti-metabolites e.g. 5-FU/MMC,</td>
</tr>
<tr>
<td></td>
<td>Antibodies to inflammatory mediators</td>
</tr>
<tr>
<td></td>
<td>Angiotensin converting enzyme or chymase inhibitors</td>
</tr>
</tbody>
</table>
Activation, migration and proliferation of fibroblasts

- Pre-operative steroids to reduce activation
- Anti-metabolites MMC 5-FU
- Methylxanthine derivatives, Mushroom lectins
- Antiproliferative gene p21(WAF-1/Cip-1)
- Photodynamic therapy

Wound contraction

- Anti-contraction agents e.g. colchicine, taxol lectins, MMP inhibitors

Fibroblast synthesis of tropocollagen glycosaminoglycans and fibronectin

- Interferon alpha, MMP inhibitors, fibrostatin-c

Collagen cross linking and modification

- Anti-cross linking agents e.g. Beta-aminopropionitrile/penicillamine

Blood vessel endothelial migration and Proliferation

- Inhibitors of angiogenesis e.g. fumagillin analogs, heparin analogs

Resolution of healing Apoptosis Disappearance of fibroblasts

- MMC 5-FU Death receptor ligands
- Stimulants of apoptosis pathways

Fibrous subconjunctival scar

The risk factors, risks of antimetabolite complications and regimen we use are summarised in tables 3-6. If intraoperative antimetabolites are indicated we now use them after the half thickness scleral flap has been cut but before the eye is entered, as there is reasonable pharmacokinetic and clinical data to suggest this is safe. If there is any problem with the scleral flap or scleral integrity or any sign of aqueous leak the use of antimetabolites can be withheld safely.

The variations in the technique used to deliver intraoperative antimetabolites may account for some of the variations in efficacy and complications seen in the literature, as may patients factors. It is very important for individual users to maintain a consistent technique and to build up experience with one technique.

Table 3: Possible risk factors for antimetabolite related complications

- Elderly patient
- Primary surgery no previous medications
- Poorly supportive scleral tissue prone to collapse
  - e.g. Myopia/buphthalmos/Ehlers Danlos
- Thin conjunctiva or sclera
- Bleb placed in interpalpebral or inferior position
Table 4: Risk factors for failure due to scarring after glaucoma filtration surgery

<table>
<thead>
<tr>
<th>Risk Factors</th>
<th>Risk 1-3+</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1) OCULAR</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neovascular glaucoma (active)</td>
<td>+ + +</td>
<td></td>
</tr>
<tr>
<td>Previous failed filtration surgery</td>
<td>+ (+)</td>
<td></td>
</tr>
<tr>
<td>Previous conjunctival surgery</td>
<td>+ +</td>
<td>Uncertain</td>
</tr>
<tr>
<td>Chronic conjunctival inflammation</td>
<td>+ + (+)</td>
<td></td>
</tr>
<tr>
<td>Previous cataract extraction (conj incision)</td>
<td>+ (+)</td>
<td></td>
</tr>
<tr>
<td>Aphakia (intracapsular extraction)</td>
<td>+ + +</td>
<td></td>
</tr>
<tr>
<td>Previous intraocular surgery</td>
<td>+ +</td>
<td>Depends on type of surgery</td>
</tr>
<tr>
<td>Uveitis (active, persistent)</td>
<td>+ +</td>
<td></td>
</tr>
<tr>
<td>A red, injected eye</td>
<td>+ +</td>
<td></td>
</tr>
<tr>
<td>Previous topical medications (beta-blockers + pilocarpine)</td>
<td>+ (+)</td>
<td>Particularly if they cause a red eye</td>
</tr>
<tr>
<td>(beta-blockers+pilocarpine +adrenaline)</td>
<td>+ + +</td>
<td></td>
</tr>
<tr>
<td>New topical medications</td>
<td>+ (+)</td>
<td></td>
</tr>
<tr>
<td>High preoperative intraocular pressure (higher with each 10mmHg rise)</td>
<td>+ (+)</td>
<td></td>
</tr>
<tr>
<td>Time since last surgery (especially if within last 30 days)</td>
<td>+</td>
<td>+ + (+)</td>
</tr>
<tr>
<td>Inferiorly located trabeculectomy</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td><strong>2) PATIENT</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Afro-Caribbean origin</td>
<td>+ +</td>
<td></td>
</tr>
<tr>
<td>May vary e.g. West vs East Africans</td>
<td>+ (+)</td>
<td></td>
</tr>
<tr>
<td>Indian subcontinent origin</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Hispanic origin</td>
<td>(+)</td>
<td></td>
</tr>
<tr>
<td>Japanese origin</td>
<td>(+)</td>
<td></td>
</tr>
<tr>
<td>Elderly (+) vs Young (+) (particularly children)</td>
<td>+ +</td>
<td></td>
</tr>
</tbody>
</table>
Table 5: Moorfields Eye Hospital (More Flow) intraoperative single dose anti-scarring regimen v2004 (Continuously evolving). Lower target pressures would suggest a stronger agent was required.

Low risk patients (Nothing or intraoperative 5-FU 50 mg/ml * ) #
- No risk factors
- Topical medications (beta-blockers/pilocarpine)
- Afro-Caribbean (Elderly)
- Youth <40 with no other risk factors

Intermediate risk patients (Intraoperative 5-FU 50 mg/ml * or MMC 0.2mg mg/ml) #
- Topical medications (adrenaline)
- Previous cataract surgery without conjunctival incision (capsule intact)
- Several low risk factors
- Combined glaucoma filtration surgery/cataract extraction
- Previous conjunctival surgery e.g. squint surgery/detachment surgery/trabeculotomy

High risk patients (Intraoperative MMC 0.5 mg/ml) #
- Neovascular glaucoma
- Chronic persistent uveitis
- Previous failed trabeculectomy/tubes
- Chronic conjunctival inflammation
- Multiple risk factors
- Aphakic glaucoma (a tube may be more appropriate in this case)

- Intraoperative beta-radiation 1000 cGy can also be used. CAT-152 (Trabio®) or humanised anti-TGF-beta2 antibody may be appropriate in the low and intermediate risk groups in the future based on the results of current studies. These groups account for the majority of patients undergoing glaucoma surgery.

# Post operative 5-fluorouracil injections can be given in addition to the intraoperative applications of antimetabolite.

Table 6: Various intraoperative anti-scarring agents applied directly to the bleb site

<table>
<thead>
<tr>
<th></th>
<th>5-FU 50 or 25 mg/ml</th>
<th>beta-radiation 1000cGy</th>
<th>MMC 0.2-0.5 mg/ml</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delivery</td>
<td>2-5 minutes</td>
<td>20 secs-3 mins</td>
<td>2-5 mins</td>
</tr>
<tr>
<td></td>
<td></td>
<td>depending on output rate</td>
<td></td>
</tr>
<tr>
<td>Cost</td>
<td>UK£1.50 10ml vial</td>
<td>Approx UK£3000</td>
<td>UK£8 2mg vial makes 5ml of 0.4 mg/ml</td>
</tr>
<tr>
<td>Availability</td>
<td>Good</td>
<td>Special ordering and</td>
<td>Good</td>
</tr>
<tr>
<td></td>
<td></td>
<td>licensing required</td>
<td></td>
</tr>
<tr>
<td>Storage</td>
<td>Room temperature</td>
<td>Lead shielded area</td>
<td>Powder stable at room temp</td>
</tr>
<tr>
<td></td>
<td>ready constituted</td>
<td></td>
<td>Unstable once reconstituted</td>
</tr>
<tr>
<td>Duration effect on</td>
<td>Several weeks</td>
<td>Several weeks</td>
<td>Months/permanent Cell death at higher range concentrations Growth arrest and cell death</td>
</tr>
<tr>
<td>fibroblast proliferation</td>
<td>Clinical effects</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>several years</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary effect</td>
<td>Growth arrest</td>
<td>Growth arrest</td>
<td></td>
</tr>
<tr>
<td>Control over area treated</td>
<td>Moderate</td>
<td>Precise</td>
<td>Moderate</td>
</tr>
<tr>
<td>treated</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
There have been reports of 5FU given intraoperatively directly into the filtration site during surgery. However, the risk of intraocular penetration is great and commercial 5FU is alkaline with a pH of almost 9.0. Injected MMC has also been occasionally reported but one case of combined central retinal artery and vein occlusion has been reported following MMC injection. 50microlitres of MMC (one drop) irreversibly damages the cornea.

Changes in area of treatment, conjunctival and scleral flap construction, and adjustable sutures have led to a dramatic difference in terms of reducing short and long term complications. This has led to a reduction in cystic areas within the bleb from 90% to 29%. The blebitis and endophthalmitis rate over 3-5 years was 20% for older limbus based techniques with a smaller treatment area versus 0% over the same period for the current technique. Falls in complication rate have also been seen in the USA in lower risk populations from approximately 6% to 0.5% to date (Paul Palmberg personal communication) If these figures were extrapolated to an approximate figure of 50,000 trabeculectomies with antimetabolite per year in the United States it is possible that bleb related complications could be avoided in many thousands of patients.

5) Conjunctival clamp We use a special conjunctival T clamp designed (Duckworth-and-Kent.com No 2-686) to hold back the conjunctiva and to prevent antimetabolite touch. This clamp maintains a pocket for antimetabolite treatment. Our experiments have shown that the antimetabolite affects mainly the area it touches, therefore protecting the edge prevents wound leaks and dehiscence.

(Figure 07 Conjunctival T clamp for holding tissue away from antimetabolite)

6) Type of sponge We use circular medical grade polyvinyl alcohol sponges used for LASIK corneal shields rather than other sponges. The sponges are cut in half and folded like a foldable lens Figure 07 and they fit through the entrance to the pocket without touching the sides (approximately 5 mm X 3 and insert about 6 of these). Figure 09
We attempt to treat as large an area as possible, including under the scleral flap. The polyvinyl alcohol sponges maintain their integrity and do not fragment. In contrast, methycellulose sponges fragment relatively easily, with an increased chance of leaving small pieces of sponge behind in the wound. The large area of treatment results in more diffuse non-cystic blebs clinically. Increasing the surface area of treatment results in a much more diffuse non-cystic area clinically. A large area prevents the development of a ring of scar tissue (the “ring of steel”) which restricts flow and promotes the development of a raised cystic avascular bleb.

7) Antimetabolite treatment duration and washout. We treat for three minutes. If we need to vary the effect of MMC we vary the concentration. We use only two concentrations (0.2 and 0.5 mg/ml) For intraoperative 5FU we use 50mg/ml, washed out with 20 ml of balanced salt solution. Pharmacokinetic experiments we have done show a rapid uptake over three minutes after which there is a plateau when relatively little drug is added for extra minutes. In the period from 1 to 3 minutes there is considerable variation in the dose delivered.

6) Paracentesis A paracentesis should be performed to allow fine control of the anterior chamber. If the paracentesis is made obliquely, Figure 10 (Figure 10 Oblique paracentesis minimising any risk to lens, for Lewicky infusion) parallel to the limbus, then the blade remains in the peripheral region of the anterior chamber with minimal chance of lens damage. Similarly, if the anterior chamber needs to be reformed in the intra- or post-operative period, a cannula introduced through an oblique paracentesis has little chance of causing lens trauma. If the entry site is placed inferiorly this can be used to gain access to the anterior chamber in the outpatient clinic if necessary. An additional advantage of a paracentesis is that it allows controlled decompression of the anterior chamber and reformation of the eye without using the sclerostomy entry site. As the scleral flap sutures are tied, the resistance of the flap to aqueous outflow can be tested by irrigating the anterior chamber with fluid through the paracentesis - enabling the opening pressure of the valve to be set with more precision. A technique that offers another level of pressure control is the use of a continuous infusion.

7) Infusion. We use an anterior segment infusion (Lewicky, Visitec) on a three way tap through the paracentesis. (Figure 11 Anterior segment infusion to maintain intraocular pressure and gauge opening pressure of sclerostomy) This maintains the pressure and rigidity of the globe throughout the surgery minimising serious complications such as intraoperative choroidal effusions particularly in high risk patients e.g. high myopes, buphthalmics. The pressure in the eye can be controlled using bottle height increasing the accuracy of the suture closure almost removing significant post operative hypotony.
8) Block removal (sclerostomy) The block removal of cornea and sclera can be achieved in a variety of ways. It can be manually cut and removed, with an appropriate blade and scissors, or a special punch instrument can be used. The sclerolimbal junction is the beginning of the blue translucent zone where the white sclera merges into clear cornea. An incision perpendicular to the surface at this point enters the anterior chamber through the anterior part of the trabecular meshwork. The incision for filtration is best done as anterior as possible as this reduces bleeding. Too posterior an incision increases the risk of the ciliary body being exposed or damaged.

If a blade and scissors are used it is difficult to cut a sclerostomy much smaller than 3 X 1.5 mm. The flap is lifted gently taking care not to cause a buttonhole. The block is outlined to at least 50% depth half without entering the anterior chamber. The eye should then be entered, the turned blade upwards and the incision opened like the action of a letter opener. If gentle traction can be applied on the flap this keeps the blade away from the iris and underlying structures. The side incisions are then completed radially cutting backwards and the base of the flap can be cut with the blade or Vannas scissors.

A punch is the method of our choice, and a variety of these are available. There is evidence that a small sclerostomy (0.5mm) is easily adequate and may minimise astigmatism and the chance of limbal aqueous flow, and maximise the chance of controlling outflow. An anterior incision is made in a similar fashion to that previously described, slightly larger than the diameter of the punch head. The punch should then be inserted ensuring that a full thickness of limbus is engaged. The punch should then be aligned perpendicular to the eye to ensure a clean non-shelved sclerostomy. (Figure 12 Small 0.5 mm titanium scleral punch to maximise flow control)

8) Peripheral iridectomy A peripheral iridectomy is performed through the sclerostomy. The reasons for carrying out a peripheral iridectomy are to prevent iris incarceration in the sclerostomy, and in some cases to relieve any element of pupillary block. It is important that the iridectomy is not too large, otherwise the patient may experience glare and monocular diplopia. The iridectomy should be made relatively broad at the base, but short in length so a large iris defect is not created. Cutting the iridectomy with the scissors parallel to the limbus helps to achieve this. A more corneal, rather than scleral sclerostomy reduces the chance of iris incarceration and bleeding. If an infusion is used, the iris can be made to present to the wound without any intraocular manipulation, minimising trauma and the need for an assistant. (Figure 13 Iris presenting through small sclerostomy with gentle pressure on back edge when infusion used. No intraocular entry necessary.)

9) Scleral flap sutures - New adjustable, releaseable and fixed  

The function of the sutures is to secure the scleral flap and provide adequate tension so that the flap acts as an aqueous flow restrictor. The tension provided by the flap and sutures is particularly important when anti-metabolites are used as this is the primary regulator of the intraocular pressure until significant healing occurs, which may be many months if mitomycin is used. It is also important when there are particular problems with the eye e.g. an eye with angle closure whose anterior chamber is likely to be flat post-operatively, unless there is adequate aqueous outflow resistance. In these cases the sutures should be tied tight to provide sufficient resistance to prevent post-operative anterior chamber shallowing.

Several types of suture can be used, interrupted which can be lasered or cut, releasable which can be pulled out in a variety of ways or a new type of suture which we have designed – the adjustable suture. We routinely place a suture at each posterior corner of the scleral flap, using a 10-0 nylon suture. Some sutures (e.g. 10-0 Alcon version) are better suited for use as adjustable or releasable sutures since they tend not to break when tension is applied to the suture during removal. Having placed the initial two sutures, the need for further sutures can be assessed by inflating the eye through the paracentesis and observing the amount of aqueous flow through the flap.

We have also developed a new type of adjustable suture which we have now evolved for about 3 years. These allow the tension to be adjusted post operatively through the conjunctiva with specially designed forceps with very smooth edges used for this adjustment of pressure.
The adjustable suture system allows a gradual titration of the intraocular pressure – more gradual than that seen with suture removal or massage. (Figure 15 transconjunctival loosening of adjustable sutures without sudden fall in intraocular pressure) We try and avoid completely cutting or removing sutures in the early post-operative phase, since this can lead to insufficient flap resistance with aqueous overdrainage and hypotony. This is a particular problem when antimetabolite therapy is used.

If the scleral flap has been sutured with non-releasable sutures, then these can be cut in the post-operative period using the technique of laser suture-lysis with a compression contact lens (e.g. Hoskins lens). There is a risk of causing a button-hole in the conjunctiva with laser suture-lysis, and this gives releasable sutures a theoretical advantage over non-releasable sutures. The use of a releasable suture technique has not been clearly shown to increase the long-term success rate of trabeculectomy, but does reduce the incidence of immediate post-operative hypotony and shallowing of the anterior chamber. Many of the sight-threatening complications of glaucoma filtration surgery are associated with hypotony. Because of the prolonged inhibition of subconjunctival scarring with antimetabolite therapy (especially with MMC), it is important to remember that hypotony can result from suture removal even several months after surgery. Late choroidal effusions and suprachoroidal haemorrhage have been reported after suture removal many months after tube drainage surgery.

10) Con junctival closure The conjunctiva can be closed with a variety of sutures. For a fornix-based flap the conjunctiva can either be closed just with one or two sutures at either end of the relieving incision, or more thorough closure can be performed with interrupted mattress sutures or a continuous suture with or without corneal grooves. We make a series of corneal grooves (“Groove closure) and do all our closure sutures through these burying the knots in the cornea so there is no discomfort from the nylon sutures (Figure 16 Corneal groove creation (5 grooves) for closure of fornix based conjunctival flap to minimise leakage and suture discomfort) (Figure 17 and 18 and 19 lateral purse string. Entry via corneal groove, purse string then exit via corneal groove and tie in groove. Repeated procedure except for the conjunctival purse string for the 3 middle sutures) This new technique has virtually eliminated central conjunctival retraction, leaks and suture discomfort.

For a limbus-based flap, a dissolving suture (e.g. vicryl) or nylon can be used to close conjunctiva using either interrupted or continuous suturing. We prefer a dissolving suture despite the theoretical slight increase in inflammation with vicryl because of patient comfort and ease of management. When suturing conjunctiva, it is important to be able to use a round-bodied rather than a spatulate needle if possible. This is because a spatulate needle hole tends to tear and increase in size, and cheesewire, whereas a round-bodied needle hole tends to close more spontaneously and leak less. This is particularly important if anti-metabolites, such as MMC are used. It is important to take secure bites of both Tenon's and conjunctiva if single closure is used, to ensure a watertight wound.

11) Post-operative medications. At the end of surgery a subconjunctival injection of steroid and antibiotic should be given 180 degrees away from the trabeculectomy site. Care should be taken to ensure this does not directly enter the eye through the sclerostomy. Mydriatics such as atropine are used by many ophthalmologists. Advantages include a relaxation of the ciliary muscle and pain relief, possible reduction of anterior chamber shallowing and malignant glaucoma, possible stabilisation of the blood aqueous barrier (Atropine mainly) and prevention of central posterior synechiae. Disadvantages include a dilated pupil which may increase the chance of lens-corneal touch if the anterior chamber is shallow, and loss of accommodation with blurred vision. With the use of the infusion and tight control of post operative flow we no longer use mydriatics routinely.
Post-operative antimetabolite injections

Post-operative injections of 5FU can be used post-operatively on their own, or even after intraoperative MMC or 5FU have been used. Subconjunctival injections of MMC have been given, but rarely significant complications have been reported so we do not use MMC injections routinely. 5FU was originally used as a planned regimen following surgery, but with the advent of intraoperative metabolites, particularly 5FU, the injections are now more usually used according to the clinical situation at each post-operative visit.

Indications
1) As part of a planned regimen in a patient with a significant risk of scarring or requiring a low post-operative intraocular pressure.
2) In a patient showing signs of scarring and imminent failure of the bleb.
3) Following a needling or reexploration procedure.
4) To prevent failure of an existing bleb after a healing stimulus e.g. cataract extraction surgery.
5) Injections may be given up to several months after surgery if there is a persistent healing response and the intraocular pressure is rising.

Technique
1) The eye is anaesthetised with several drops of topical amethocaine. It may also be useful to blanch the conjunctiva with a drop of adrenaline 0.01% or pheneylephrine 2.5% if there is no contraindication, as this may reduce the incidence of post injection subconjunctival haemorrhage.
2) Quantity and concentration. The original regime involved injections of 5 mg of 5FU diluted with 0.5 mls of saline. 5FU is now generally given in a concentration directly from the bottle, which is either 0.1 mls of a 50 mg/ml solution or 0.2 mls of a 25 mg/ml solution (i.e. injection dose = 5 mg).
3) A thin needle is advantageous as it reduces the reflux of 5FU into the tear film. For convenience we use a presterilised insulin syringe with an integral 27 gauge needle.
4) A lid speculum is inserted to improve access.
5) Site of injection. 5FU was originally given 180 degrees from the bleb to minimise the risk of intraocular entry of the 5FU solution which has an alkaline pH. We now give the injection about 90 degrees from the bleb to maximise the effect. Occasionally the injection can be given deep in the upper fornix away from the drainage bleb if there is very good exposure. The conjunctiva is gently lifted with a non toothed forceps and the needle inserted subconjunctivally. If the needle is too deep there is a danger of scleral bleeding and direct tracking into the eye. The bleb resulting from the injection is slowly raised and watched as it advances towards the drainage bleb area, and injecting should stop just before the injection bleb meets the drainage area. Great care should be taken, particularly in a soft eye, as 5FU may enter the eye much more easily in a soft eye.
6) The needle should be left in place for a few seconds as this helps to seal off the entry site and reduce leakage of 5FU into the tear film.
7) Any remnant 5FU in the tear film should be irrigated out. If amethocaine eyedrops are used after a 5FU injection a fine white precipitate in the tear film indicates that there is 5FU present. Washing out the fornix may reduce the incidence of corneal complications.
8) We have developed a new technique of 5-FU preceded by subconjunctival Haelon GV™. This “viscoelastic wall” prevents leakage of 5FU back into the tear film and enhances the effect of the 5-FU (Figure 20 VIscoelastic wall and 5-FU lake )

Post-operative management of glaucoma filtration surgery

1) Topical steroids. It is important to suppress the wound healing response in the early to intermediate post-operative period. Steroids are initially prescribed 2 hourly for the first 2 weeks and then the dosage is adjusted according to bleb morphology. Patients routinely receive a reducing dose of topical
steroids for approximately 8 weeks post-operatively. We use the strongest steroid available, at present Prednisolone acetate 1%.

2) Topical antibiotics. The patient usually receives antibiotics for about 4 weeks post-operatively.

3) Topical mydriatic / cycloplegic agents. Use of these agents varies between surgeons. They may be useful in preventing post-operative synechiae, help to deepen the anterior chamber (particularly in eyes at high risk of developing a shallow anterior chamber or malignant glaucoma), and reduce spasm due to ciliary spasm. Disadvantages include increased visual blurring and a possible increased risk of lens corneal touch if the anterior chamber is shallow.

4) Topical non-steroidal anti-inflammatory drugs. These may be useful in selected patients but their efficacy is not proven.

5) Oral steroids. The use of these powerful drugs with potentially dangerous systemic side-effects is not routine. However, there are certain patients (e.g. those with severe uveitic glaucoma) in whom the benefits of use will outweigh the risks. When used, systemic steroids should be started in the pre-operative period and there should be good communication between the ophthalmic surgeon and the patient's family doctor and other physicians.

6) Antimetabolite therapy. Subconjunctival 5FU can be given in the post-operative period to modulate wound healing. It is essential that if 5FU is used, it is given as soon as bleb failure is detected. Signs of impending bleb failure include; changes in bleb morphology with increased bleb vascularity, thickening of conjunctiva and Tenon's capsule, reduction in bleb size and height, reduction of conjunctival microcysts and progressive elevation of the IOP. The formation of focal bleb encapsulation may result from continued subconjunctival fibrosis.

7) Complications. The best management of complications is to anticipate and prevent them.

**Intraoperative complications (glaucoma filtration surgery)**

_i) Conjunctival tear_ Conjunctival tears can be a serious problem, particularly if anti-metabolites are used. The most common cause of a conjunctival tear is surgical damage from scissors during the dissection process. This is particularly likely if there has been previous surgery and adhesions are present.

**Prevention**

1) Slow dissection with continual reassessment of the plane of dissection.
2) If there is significant scarring, it is best to proceed slowly with very small cuts, to minimise any tearing action. 3) Use G.Adrenaline to reduce tissue vascularity and bleeding. 4) inject subconjunctival saline to demarcate scar tissue and open up tissue planes (NB very useful tip)

**Management**

1) If a conjunctival tear occurs, and anti-metabolites are not used, it can usually be repaired by a simple purse-string vicryl suture, on a vascular needle.
2) If anti-metabolites are used (especially MMC), it may be necessary to bring in tissue that has not been exposed to the anti-metabolite. This can be done by dissecting an attached flap of Tenon's capsule, from an area distant to the treated area, and then rotating it underneath the conjunctiva and then sewing it in as a living patch underneath the tear.

_ii) Scleral flap damage_

**Prevention**

1) Reduce handling of scleral flap to a minimum.
2) Do not make flaps too thin as they cheese-wire and tear very easily. The eye should not be opened until the scleral flap has been fully completed.

**Management**

1) If the scleral flap is severely damaged during the dissection, then surgery should not proceed at that site and a new scleral flap created in an area of undamaged sclera.
2) If minor flap damage occurs, this may have to be repaired with the 10/0 nylon suture. If very severe damage has occurred and the sclerostomy cannot be secured, then a scleral patch from another area or a donor, or processed pericardium may have to be sewn onto the operation site.

iii) Conjunctival, scleral and iris bleeding

Prevention
1) Bleeding can be avoided by appropriate use of cautery. Close attention to haemostasis including clot removal is important, because blood is a very potent stimulus for fibrosis.
2) Installation of G adrenaline 0.01% at the start of surgery help to reduce bleeding in the area.
3) Stop aspirin and anticoagulants preoperatively if possible.

Management
1) If there is bleeding following the peripheral iridectomy, it is best to wait, leaving the flap slightly open, to allow the blood to exit the eye, rather than collecting in the anterior chamber. In the vast majority of cases, the bleeding stops within a minute or two. The clot can then be irrigated out, and the operation completed.
2) If the bleeding continues the intraocular pressure in the eye should be raised, with an anterior chamber infusion if necessary.

iv) Suprachoroidal haemorrhage

Fortunately this is very rare intra-operatively. The intraocular contents will come forward and the pressure will rise acutely.

Prevention
1) Caution in advising surgery in high risk eyes (e.g. other eye expulsive haemorrhage)
2) Avoid operating on inflamed eyes until quieter or eyes with high pressures
3) Maintain intraoperative pressure (preplace sutures, use an anterior chamber infusion throughout procedure)
4) Maintain post operative intraocular pressure (e.g. viscoelastic, C3F8 gas in aphakic eyes)
5) Stop aspirin and anticoagulants if possible and avoid valsalva manoeuvres post operatively
6) In nanophthalmic eyes, scleral decompression may be required before entry into the eye. The diagnosis will be missed unless it is looked for clinically (small eyes) and with ultrasound (short eye and thick ocular coat).

Management
1) Close all wounds rapidly
2) When eye is secured, assess posterior segment and confirm diagnosis and presence of choroidals haemorrhage. If they are peripheral and not impinging on central vision consider leaving. If haemorrhage is extensive then consider drainage through one or two sclerostomies. Drainage must be performed before the blood clots to be effective at the time of surgery.

v) Vitreous loss

Fortunately, this very rarely occurs.

Prevention
1) Keep sclerostomy as anterior as possible.
2) Note any iridodonesis and subluxed lenses preoperatively - consider tube surgery or filtration with MMC if lensectomy and anterior vitrectomy inevitable.

Management
1) Anterior vitrectomy
2) Post-operative 5FU will be required as there is an increased chance of filtration failure.

vi) Wound leak

Prevention
1) Use round vascular needle (e.g. BV needle) which reduces conjunctival leakage and buttonholing
2) Place incision in limbal based flap as far away from limbus as possible, deep in the fornix
3) Use extra mattress suture(s) to close fornix based conjunctival flaps
4) Avoid conjunctival dissection in scarred areas if possible - conjunctival buttonholing is more likely in these areas due to multiple adhesions

**Management**

1) Small leaks often settle spontaneously with observation. If leaks persist then treatment options include use of a pressure dressing, bandage contact lens, Simmonds' shell or suppression of aqueous production with acetazolamide.
2) Significant leaks with hypotony and choroidal effusions are best managed by resuturing the wound.

**Post operative complications (glaucoma filtration surgery)**

1) "Wipe out" of remaining field/vision
   This is a very rare but important complication of filtration surgery. It is thought to occur more commonly if there is advanced field loss, particularly if the field loss is within 10 degrees of fixation, although this has not been conclusively proven.
   **Prevention**
   1) Check intraocular pressure in the first few hours after surgery to detect and treat any pressure spike
   2) Take precautions to avoid peri- and post-operative hypotony as well as acute disc swelling may also compromise a very damaged nerve.
   3) Avoid episodes of peri-operative systemic hypotension.

2) Shallow/flat anterior chamber
   Shallowing of the anterior chamber post-filtration surgery is a common event. Certain eyes have a higher risk of this complication, particularly hypermetropic eyes with angle closure glaucoma. The key to successful management of a shallow anterior chamber is to identify the cause. If there is lens-corneal touch surgical intervention is required immediately to prevent corneal decompensation. Reformation of the anterior chamber can be performed using balanced salt solution, gas or a viscoelastic. A high density viscoelastic such as haelon GV may be particularly useful. The procedure is safer and easier if an oblique temporal paracentesis was performed at the time of initial surgery. Anterior chamber reformation can be performed at the slit lamp if an appropriate paracentesis exists.

3) Hypotony: due to aqueous overdrainage
   The use of antimetabolites (especially MMC) has increased the incidence of hypotony due to an over draining bleb. In glaucoma filtration surgery some degree of hypotony with an IOP less than 6 mmHg is common in the first few days following surgery, particularly if tight suturing techniques are not used. Most cases will settle without intervention. If the hypotony persists and produces a hypotonous maculopathy then surgical treatment is indicated (see later section).
   **Prevention**
   1) Close scleral flap securely. Adjustable/Releasable sutures are very useful. Multiple sutures may be required particularly if MMC is used
   2) Use an infusion with a known pressure to regulate opening pressure
   3) Do not make scleral flap too small or thin, particularly if MMC used, otherwise outflow cannot be adequately restricted
   4) Do not release sutures too early. If MMCis used suture release (even months after surgery) may result in hypotony. It is preferable to try to loosen releasable sutures with massage rather than release them.
5) Caution when using strong antimetabolites in patients with a high risk of hypotony related complications, particularly patients who have thin or abnormal sclerae e.g. myopes, buphthamics and those with collagen abnormalities

iv) Choroidal effusion

Choroidal effusions are common in eyes that are hypotonous following filtration surgery. The collection of fluid (high protein content) in the suprachoroidal space is produced by transudation from leaky capillaries in the choriocapillaris.

Prevention
1) Take measures to prevent hypotony (see above).

Management
1) Cycloplegic mydriatic agents and frequent topical steroids.
2) Surgical intervention is rarely required, but signs that drainage of the effusions may be is needed include: evidence of lens-corneal touch with corneal oedema, bleb failure with increasing IOP, marked anterior segment inflammation and apposition of the effusions ("kissing choroidals").
3) If the IOP is normal then other causes of choroidal effusion should be considered including scleritis, and low serum protein levels and nanophthalmos.

v) Raised intraocular pressure

A high IOP after filtration surgery is one of the commonest complications of filtration surgery. It is almost always due to inadequate aqueous outflow. Treatment depends on the site of obstruction. Sometimes obstruction can occur in several sites at once. The sites of obstruction are:

a) Posterior diversion of aqueous (Malignant glaucoma)

In malignant glaucoma the aqueous is misdirected backwards into the vitreous cavity and is prevented from flowing anteriorly by the anterior vitreous face. The patient usually presents with a shallow anterior chamber, and an elevated intraocular pressure several days after surgery. Ultrasound reveals hypo-echogenic areas on ultrasound. It has been observed that ciliary processes are rotated anteriorly in malignant glaucoma such that they press against the lens equator and prevent anterior flow of aqueous. It has also been noted that the anterior vitreous hyaloid is abnormally positioned plugging spaces between ciliary processes. An acute pupil block or choroidal haemorrhage can sometimes give a similar picture but is easily excluded clinically. The eye may have a predisposing risk factors such as hypermetropia, and angle closure glaucoma.

Prevention
1) Identify high-risk eyes pre-operatively (Ultrasonic measurement of axial length if necessary). It is important to identify nanophthalomic eyes, as prophylactic sclerotomies may be required.
2) Ensure that there is a relatively high resistance at the level of the scleral flap by tight closure. If necessary manage raised intraocular pressure medically in the early post-operative period, releasing sutures later. Overdrainage of aqueous in the early post-operative period must be avoided in high risk eyes.
3) Use of cycloplegics especially G. Atropine or homatropine is useful.
4) In high risk eyes if some cataract is present a combined procedure may debulk lens volume. A rigid one piece implant may help prevent a flat anterior chamber. The capsulorrhexis should be kept relatively small to prevent lens implant/pupil capture occurring if the anterior chamber shallows. If malignant glaucoma does develop this is easier to manage in a pseudophakic eye.

Management
1) Ensure peripheral iridectomy is patent
2) Mydriatics. Atropine 1% and phenylephrine 10% (if no contraindication)
3) Aqueous suppressive agents with osmotics if necessary.
4) If the ciliary processes are visible on gonioscopy such as in an eye with a broad iridectomy, direct argon laser to the ciliary processes may break the attack. However, corneal oedema and the
shallowed anterior chamber often make this very difficult.
5) Disruption of peripheral anterior vitreous face using a Nd:YAG laser. The aim of this procedure is to create a pathway for fluid to move from the posterior segment to the anterior chamber. To achieve this goal it is usually necessary to disrupt the peripheral anterior vitreous face. Disruption of the central hyaloid often fails to produce an adequate pathway for fluid movement. It can be difficult to remove the anterior vitreous face particularly in a phakic eye where the risk of lenticular damage is high. If the patient is phakic but has significant cataract consideration should be given to lens extraction and this increases the chance of successful disruption of the anterior hyaloid face.

Good visualisation and precise focusing of the Nd:YAG laser are important. It is useful to have a patent PI in order to achieve adequate access to the peripheral anterior hyaloid. As soon as the hyaloid is disrupted the anterior chamber will be observed to deepen. In pseudophakic eyes one must create a passage through any tissue that intervenes between the PI and hyaloid, including lens capsule and any cortical lens remnants. If the eye is inflamed there may be condensations of anterior hyaloid which are adherent to adjacent structures, and which create restricted pockets of misdirected aqueous.
6) If a surgical vitrectomy is necessary, this can be performed through the peripheral iridectomy if the patient is pseudophakic, but will required pars plana approach if the patient is phakic.

b) Pupil block
If pupil block occurs after filtration surgery the peripheral iridectomy is non-patent or may be blocked by fibrin. The anterior chamber is shallow with some iris bombe.

Management
1) Pressure lowering treatments as necessary
2) Nd:YAG laser iridotomy
3) Pupil dilatation to break any synechiae
4) Steroids to reduce inflammatory exudate.

c) Fistula blockage.
If the rise in intraocular pressure occurs in the first 1-2 weeks fistula obstruction is the most common cause. The bleb is usually flat. The most common cause is scleral flap sutures that are too tight. Other causes include fibrin and blood at the level of the flap and subconjunctival space. Gonioscopy will help to identify those cases in which the internal aspect of the sclerostomy is blocked by iris, ciliary processes, vitreous or blood; or in which there has been failure to correctly excise the corneo-scleral block.

Prevention
1) Ensure adequate size and clean excision of corneo-scleral block.
2) Avoid a posteriorly sited sclerostomy which increases chance of ciliary body or blood obstruction
3) Create and use a paracentesis to check the opening pressure of the scleral flap intraoperatively.

Management
1) Gentle massage at posterior lip of sclerostomy may loosen any adhesions and restart aqueous flow through the fistula. This may also loosen any mild internal sclerostomy blockage. The application of focal pressure through the eyelids initially may be all that is required. Otherwise, pressure applied more focally (with a sterile plastic ointment applicator) is more effective than diffuse digital massage through the lids. If releasable sutures have been used this manoeuvre tends to loosen the tension in the knot and reset a lower opening pressure at the scleral valve. One problem with completely removing releasable sutures or cutting a scleral flap suture with the argon laser is that the resistance to flow at that point in the flap drops suddenly, with loss of control and risk of sudden aqueous overdrainage and hypotony. The patient should be re-examined about 30 minutes after massage to check that the IOP has not increased again.
2) If massage fails to establish adequate aqueous drainage through the scleral flap then it may be necessary to remove the releasable suture or perform argon laser suture-lysis.
3) Application of argon or Nd:YAG laser to the internal aspect of the sclerostomy can be used to remove any tissue blocking the opening.
d) Subconjunctival fibrosis

Blebs that were previously functioning may become encysted or encapsulated during the first few months after filtration surgery because of the wound healing response. These blebs have an elevated, tense, dome-shaped structure associated with an elevated IOP. (Figure 21 Severely encysted bleb) There is a fibrotic healing response within Tenon's capsule, particularly around the edge of the cyst, but there may also be compression of the subconjunctival tissues which reduces transconjunctival aqueous flow. In addition, some blebs are lined with fibrin. Patients who have received previous topical sympathomimetic agents may be at higher risk of developing bleb encapsulation.

Management
1) Intensive topical steroids.
2) Aqueous suppressant therapy may help by reducing the compaction of the inner layers of the bleb, allowing increased transconjunctival aqueous flow.
3) Needling of encapsulated bleb. This procedure can be performed under topical anaesthesia at the slit-lamp. The conjunctival vascularity is reduced by prior instillation of G.Adrenaline 0.01% or G.Phenylephrine 2.5%. Aqueous iodine (5%) is instilled into the conjunctival sac and then washed out after several minutes. The patient is asked to look down and an assistant or speculum used to retract the upper lid. A narrow gauge needle (e.g. 29G) is passed through the conjunctiva several millimetres to one side of the bleb. The needle is advanced until the tip punctures the cyst wall. The needle is then gently moved from side to side to enlarge the hole in the wall of the cyst. The act of needling is likely to reactivate the wound healing process in the region of the bleb, and for this reason a subconjunctival injection of 5FU (5 mg) is given 900 away from the bleb. Topical steroids and antibiotics are given after the needling. It is important to be aware that excessive needling can result in a precipitous drop in IOP and can potentially result in all the complications of hypotony including suprachoroidal haemorrhage.

e) Late bleb leak focal or diffuse:

Blebs can start to leak months or years after surgery, this is particularly so if an unguarded sclerostomy was performed or antimetabolites (particularly MMC) were used at surgery. The leak can be focal and single or diffuse with multiple "sweating" areas. (Figure 22 leaking bleb secondary to cystic change)

Prevention
1) Avoid unguarded sclerostomies. Full thickness sclerostomies are much more likely to result in thin cystic blebs, even without antimetabolite use.
2) Avoid excessive use of antimetabolites.

Management
The decision to treat depends on several factors including; patient factors (including symptoms), the size of the leak, bleb morphology, risk factors for infection, and the presence of hypotony and complications of hypotony such as macular oedema. Small leaks may settle spontaneously. The range of treatment options include:
1) Large diameter contact lenses.
2) Bleb compression sutures. 9/0 nylon sutures are sewn across the bleb compressing it around the leak site. This can be combined with blood injection. While the sutures stay in situ the patient should continue on prophylactic antibiotics. (Figure 13)
3) Laser treatment to the deep scleral flap.
4) Trichloracetic acid painted on bleb.
5) Injections of autologous blood (1-2 ml). This can be given both into and around the bleb. The pressure may rise immediately after injection due to blood clot obstructing outflow. However, the pressure will fall when the fibrinolytic system is activated. At this later stage only secondary healing stimulated by the injection will increase the intraocular pressure. If intrableb injection is used the blood may enter the anterior chamber and cause a hyphaema or the vitreous cavity (particularly in
pseudo or aphakic eyes) resulting in a vitreous haemorrhage. The use of concurrent viscoelastic in the anterior chamber to raise pressure and prevent blood entry. However, this may result in a large, persistent pressure rise and is not advised.

6) Refashioning of the bleb. This is the most extensive treatment but also the most effective as the area is effectively reconstructed. The cystic avascular area is resected and viable vascularised conjunctiva is brought down from above. A lamellar scleral patch is sewn onto the old trabeculectomy site, and reduces the chance of a recurrence of bleb thinning and leakage. If a scleral patch is not used, then there is a very high chance if a recurrence of the cystic area in the long term. (Figure 14) The technique is very effective in stopping leaks, but can be complicated by a persistent rise in IOP.

5a) Quilting sutures can be used to tack down an exuberant conjunctiva.

7) Cataract surgery may produce an inflammatory reaction which may stimulate wound healing. If a significant cataract is present it may be appropriate to perform cataract surgery if the bleb is only slightly overdraining. The surgery may stimulate enough healing to restore the bleb to an acceptable condition. However, it is important to remember that biometry may be different in a hypotonous eye.

f) Early infection - blebitis and endophthalmitis

Prevention
1) Identify high risk patients (e.g. blepharitis) and manage pre-operatively.
2) Pre-operative aqueous iodine to lids and conjunctival sac.
3) Make sure that there are no lashes in the operative field.
4) If releasable sutures are used they should be either buried or removed early if exposed.

g) Late infection

Prevention
1) Avoid overtreating patient with antimetabolite.
2) Avoid unguarded sclerostomy and very thin scleral flaps, which may necrose (especially if MMC is used).
3) Avoid very focal small areas of antimetabolite exposure. Use Larger areas of treatment and certain agents (e.g. beta-irradiation) produce more diffuse and less cystic blebs.
4) Avoid blebs situated in the interpalpebral or inferior area. The blebitis/scleritis and infection rate may be 5-10 times in these areas compared to blebs under upper lid. Use tubes or other therapies rather than place blebs inferiorly.

Management

Bleb infection is an emergency. Patients should be told to seek ophthalmological attention immediately if they develop a purulent conjunctivitis. If there is a suggestion of endophthalmitis the patient should be treated as an endophthalmitis and undergo swabs, aqueous and vitreous taps. Even with bleb associated endophthalmitis swabs and aqueous taps may be culture negative with positive vitreous cultures, usually if antibiotic therapy has been started but even if it has not. The patient should then receive intravitreal antibiotics. If there is marked vitreous activity a vitrectomy should be considered to debulk the infective agent and toxins. Haemophilus an streptococcus are the commonest organisms causing bleb related endophthalmitis and any antibiotic regimen should cover these organisms.

h) Cataract

Cataract progression is a very common complication of glaucoma filtration surgery. Several situations increase cataract progression including lens/corneal touch, lens trauma, inflammation, hypotony and the use of intraoperative MMC.

Prevention
1) Take precautions to avoid post-operative hypotony and flat anterior chambers.
2) Avoid direct lens trauma - use of an oblique paracentesis parallel to the limbus minimises the possibility of any lens trauma lowers the chance of damage when reforming the anterior chamber and or testing the resistance of the scleral flap.
3) Consider combined cataract and filtration surgery in primary glaucoma if there is significant lens opacity.

i) Ptosis and strabismus
Prevention
1) Use a corneal traction suture rather than a superior rectus suture.
2) Avoid excessive traction on the eye which stretches levator aponeurosis.
3) Avoid rectus muscle traction sutures when placing tube implants where possible.
4) When dissecting a limbus based flap incise the conjunctiva and Tenon's as separate layers to prevent damage to the superior rectus muscle.
5) Take care with posteriorly placed sponges soaked in antimetabolite as MMC is toxic to muscle.
Management
1) Conservative - most cases settle spontaneously.
2) Appropriate surgery (e.g. to repair a levator dehiscence) may be required in some cases.

j) Astigmatism
Prevention
1) Keep actual sclerostomy and amount of tissue removed to a minimum, particularly if scleral rigidity is low
2) Keep scleral flap size to minimal size required to achieve control of flow (but noting that relatively larger flaps may be needed with strong antimetabolites)
3) Use oblique rather than radial sutures on scleral flap where possible

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